Deepening Computational Thinking for English Learners by Integrating Community-Based Environmental Literacy

Over the last six years, the "CONECTAR" Research-Practice Partnership has developed one of the first computational thinking curricula targeted at the needs of English language learners. By integrating language and literacy scaffolding in both English and Spanish; culturally-sustaining lessons drawing on and promoting students' community assets and resources; scaffolded inquiry in which we systematically teach students the elements of coding as they begin to develop their own projects; and a resource-rich professional development that gives novice elementary teachers the knowledge, skills, and tools to both learn coding and learn how to teach it to their diverse students, we have demonstrated that a weekly Scratch-based lesson can boost Latino[1] English learners' computational thinking, computer science identity, and standardized math and science scores compared to students without the curriculum.

Two years of the curriculum have been developed (ACT 1 and ACT 2). We now propose to scale up and deepen this curriculum through development of a third year (ACT 3) focused on integration of computational thinking and community-based environmental literacy. We first review what we have accomplished to date and then set out the new research plan.

Results from Prior Projects

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Award number: 1923136 **Amount**:$1,060,000 **Dates**: 09/01/2019-08/31/2023
Title: CONECTAR 2.0: *Collaborative Network of Educators for Computational Thinking for All Research*
Intellectual Merit: This project has developed one of the first elementary school computational thinking curricula congruent with the cultural and linguistic resources of young Latino learners. The curriculum, iteratively developed over years through a co-design process with teachers, includes the following: Language: Substantial language support in both English and Spanish consistent with the recommendation of NASEM (2018). Students learn the discourse of computer science through collaborative interaction and strengthen their literacy by reading and watching videos about diverse computer science pioneers, completing written reflections, and coding stories in narrative and informative genres. Culture: Culturally-sustaining projects are related to students' lives, families, and communities. Curriculum includes culturally-valued role models. Coding: Guided coding inquiry using the innovative TIPP&SEE (Salac et al., 2021) method which empowers students with little prior computing experience to examine and understand Scratch programs before developing their own. Teacher Development: We have developed a professional development program that supports elementary teachers' teaching coding in a way that builds on their students' cultural and linguistic assets.

Our research has demonstrated that the curriculum helps predominantly low-income Latino students, including large numbers identified as English learners, learn the discourse of computer science, advance their coding skills, and develop a strong computer science identity, all while achieving greater growth in their standardized reading and math skills than their peers who do not have access to the curriculum—and that elementary school teachers of such students are able to successfully teach the curriculum without any prior coding experience (Jacob, Parker, & Warschauer, 2022).

Broader Impact: The RPP began with a partnership between the University of California, Irvine (UCI) and Santa Ana Unified School District (SAUSD), and, over the last year, brought in Montebello Unified School District (MUSD) and El Sol Science and Arts Academy (El Sol), a dual immersion public charter school in Santa Ana. In each of these three partner school districts, over 95% of students are Latino and about half of elementary students are designated as English learners The curriculum has thus far reached some two thousand elementary students in our partner districts, and, with an Education Innovation and Research grant from the US Department of Education, the curriculum will now be made available to all third- and fourth-grade classrooms in the districts. It has also been adopted by Boston Public Schools and Chicago Public Schools. Hundreds of unique visitors from 30 states and 24 countries have accessed the

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[1] Though we recognize the benefits of using gender-neutral terms such as Latinx or Latine, we defer to the common practices among our school district partners that use the term Latino.

curriculum on our project website, and teachers from multiple districts and several other countries have joined our professional development trainings. Through a Research Experience for Undergraduates grant, we have trained 10 undergraduates, all from underrepresented groups, in computer science education research skills, and the 6 graduate students and postdocs working on the project all come from groups underrepresented in computing.

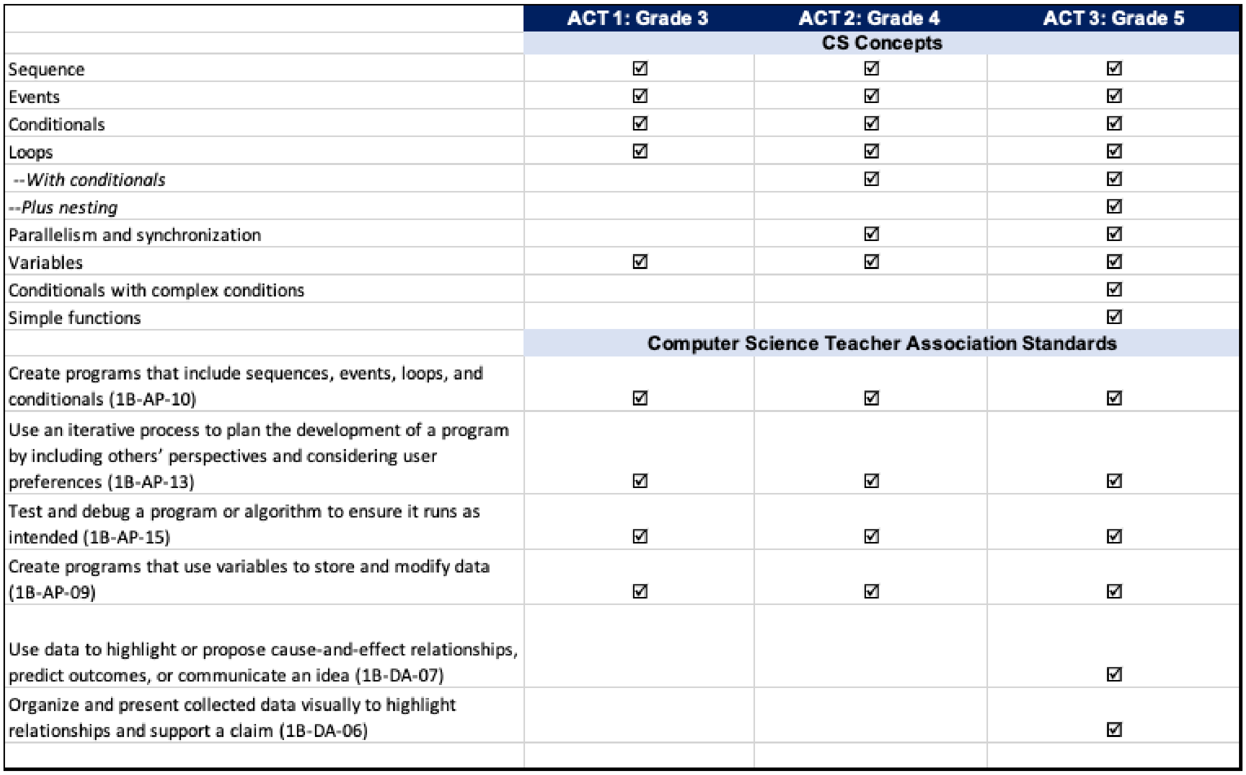
Publications: This project has resulted in 15 refereed publications in education and CS venues, including publications on successful approaches for teaching computer science language and concepts (Eatinger et al., in press; Jacob, Garcia, & Warschauer, 2020; Nguyen et al., 2020a), examining and promoting identity of multilingual students in computer science education (Jacob, Montoya, et al., 2022; Jacob, Montoya, & Warschauer, 2022a, 2022b; Jacob et al., 2021; Ojeda Ramirez et al., in press), assessing computational thinking skills (Nguyen et al., 2020b; Parker et al., 2021), integrating computational thinking into English Language Arts (Jacob, Parker, & Warschauer, 2022; Jacob & Warschauer, 2018), and developing and assessing computational thinking skills for multilingual students and exceptional students (Jacob, Nguyen, et al., 2020; Prado et al., 2022; Saito-Stehberger et al., 2021).

Products: The curriculum materials including lesson plans, student workbook, virtual resources, and Scratch tutorials are accessible to the general public on our website under a Creative Commons Attribution NonCommercial-ShareAlike 4.0 International license. These publicly accessible materials include the Assessment of Computing for Elementary Students (ACES) that we developed and validated.

Deepening the Learning Experience by Integrating Environmental Literacy

Now that two years of the curriculum have been developed and are being introduced throughout the partner school districts, we have been discussing within the RPP how to deepen and extend students' learning experiences. The partners agree that the integration of computational thinking with language and literacy has been an invaluable and innovative contribution that has helped their students thrive. At the same time, MUSD suggested that by the third year of the curriculum, we might also be able to integrate

Table 1: Trajectory of the curriculum



	ACT 1: Grade 3	ACT 2: Grade 4	ACT 3: Grade 5
		CS Concepts	
Sequence	☑	☑	☑
Events	☑	☑	☑
Conditionals	☑	☑	☑
Loops	☑	☑	☑
--With conditionals		☑	☑
--Plus nesting			☑
Parallelism and synchronization		☑	☑
Variables	☑	☑	☑
Conditionals with complex conditions			☑
Simple functions			☑
		Computer Science Teacher Association Standards	
Create programs that include sequences, events, loops, and conditionals (1B-AP-10)	☑	☑	☑
Use an iterative process to plan the development of a program by including others' perspectives and considering user preferences (1B-AP-13)	☑	☑	☑
Test and debug a program or algorithm to ensure it runs as intended (1B-AP-15)	☑	☑	☑
Create programs that use variables to store and modify data (1B-AP-09)	☑	☑	☑
Use data to highlight or propose cause-and-effect relationships, predict outcomes, or communicate an idea (1B-DA-07)			☑
Organize and present collected data visually to highlight relationships and support a claim (1B-DA-06)			☑

new content. They were particularly interested in integrating environmental literacy into the curriculum because of its interdisciplinary nature and cultural relevance. The partners agreed to create a third year of the curriculum (ACT 3, to be taught in fifth-grade) that would focus on applications in the area of community-based environmental literacy. The trajectory of the CS concepts in the first two years (ACT 1 and ACT 2) and the ACT 3 curriculum is presented in Table 1.

Our work in this area builds on the Environment as an Integrating Context (EIC) model developed by the State Education and Environment Roundtable (SEER), founded by a group of 12 state departments of education in 1995 with the goal of strengthening student achievement by using high-quality environmental education as a critical component of classroom instruction. SEER has a particularly strong presence in California, where it has had a lengthy partnership with the Department of Education and has worked closely with MUSD and more than 20 other school districts to integrate environmental literacy into science, history-social science, health, visual and performing arts, world languages, and mathematics.

SEER implements the EIC model for improving student learning. Learning based on the EIC model is about using a school's surroundings and community as a framework within which students can construct their own learning, guided by teachers and administrators using proven educational practices. SEER uses local natural and community surroundings as context; community-based investigations with opportunities for environmental service-learning that offer both minds-on and hands-on experiences; learner-centered, constructivist approaches adapted to the needs and abilities of individual students; and combinations of cooperative and independent learning that promote collaboration among students while encouraging individual students to maximize their potential.

This EIC model is already being widely implemented in MUSD and has been enthusiastically embraced by the leadership of the other two school district partners. Integrating this type of environmental literacy work with computational thinking allows us to amplify the benefits of both, as students can better understand computational thinking by seeing how it can be applied and better understand the environment by using computational thinking to model and visualize the phenomena they are investigating. Using computational thinking in support of authentic, important community-based activities should also be engaging. In addition, the combination makes the teaching of both of these important new curricular topics—computational thinking and environmental literacy—more feasible and appealing as they can be taught in an integrated fashion rather than addressed separately. And it provides additional opportunities for a language-rich and culturally-sustaining context for computing (Lieberman, 2013).

Project Fresa

A community-based digital literacy initiative called “Project Fresa” (Strawberry Project) for fifth-grade students in Oxnard, California, investigated the working conditions of farmworkers in nearby strawberry farms. Students surveyed and interviewed the workers in both Spanish and English, gathered data about working conditions. and communicated what they learned through graphs, figures, poetry, artwork, and digital stories. The project strongly engaged students, demonstrated for them the power of their inquiry and voices, provided compelling real-world opportunities for language practice and use; and developed their knowledge about critical issues affecting the local community, such as use of pesticides on farms; all while advancing their digital literacy skills (Warschauer, 2007).

Integrating computational thinking with community-based environmental literacy can be especially effective with Latino students, who place great value on giving back to their communities and gravitate toward academic subjects that heighten their ability to do so (Jacob, Montoya, & Warschauer, 2022b; for a similar effort based on digital literacy, see *Project Fresa* in side panel). A disconnected computer science curriculum, which views CS as a highly esoteric topic of study irrelevant to broader domains and students' lives, has long been associated with elitism in computer science education and making the subject less accessible to diverse learners (see, e.g., Margolis et al., 2008). In contrast, a community-based environmental literacy curriculum provides a powerful medium for positive integration of CS, as it demonstrates the value of CS in a domain important to improving local communities. This is especially the case with the EIC approach to environmental literacy, which involves students in identifying and investigating environmental issues critical to their own communities. Environmental justice has become a high-priority topic at the state and national level; the United States Environmental Principles and Concepts (EP&Cs) and California EP&Cs, the curricular expectations that guide environmental literacy integrated in interdisciplinary subjects, focus on students exploring issues in their local communities and finding opportunities to make tangible differences while understanding the political, socio-cultural, economic, and other factors that can influence the decisions affecting the environment (Lieberman, 2017).

To explore this integrative approach, we recently conducted a pilot study in a fifth-grade MUSD classroom in a low-income Latino community in collaboration with environmental literacy specialists from the school and district. The students in the class identified the presence and absence of trees in their community as an important factor impacting the local environment, specifically as a factor related to pollution. First, the students learned the concept of a system and how the parts interact to serve a purpose. Emphasis was placed on the interdependency of the parts of a system and how changing one part can affect the system. Next, students read text and watched videos on causes and impacts of pollution, and then coded an animated model in Scratch that narrated how various parts of an environment affect pollution. Understanding the significance of the quantity of trees in a community, students brought the abstract lessons to their own community when they viewed their neighborhood Tree Equity Score (a metric showing how much tree canopy and surface temperature align with socioeconomic and racial factors in the United States) online using the national data source. We found this experience to be a productive pathway for students to become aware of their environment, to discuss it collectively, and to work together to brainstorm possible solutions to identified issues. Both the students and teacher enthusiastically and successfully carried out this work. Notably, this project took place in a special day class for children with mild to moderate disabilities, the majority of whom were English language learners and none of whom had previously learned Scratch. Their success with the project provides strong evidence of the feasibility of integrating environmental literacy and computational thinking in our partner schools. The student learning objectives and the computer science, science, and English language standards[2] that align to the example learning activity described above can be found in Table 2. In addition, our overall curriculum, ACT 3, will align with the NGSS standards included in the California Science Test (CAST) for fifth-graders.

Table 2: Sample learning activity aligned to Grade 5 NGSS, CS, and language/literacy standards

Activity: Introduction to systems - Identifying causes and effects of pollution in the environment	
Student Learning Objectives: ● Define the components, processes, interactions, and function of a system. ● Discern what is a system and what is not a system. ● Identify components in a system and articulate how they are related. ● Code a Scratch project to communicate the causes and effects of the components in the system. ● Identify sources that impact pollution in their community and brainstorm actions they can take.	
Computer Science Concepts: Sequences, events, loops, conditionals, parallelism and synchronization variables (input), simple functions	
California’s Next Generation Science Standards (CA NGSS)	
5-ESS3-1	Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.
3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
ESS3.C	Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. Individuals and communities are doing things to help protect Earth’s resources and environments.

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[2] CSTA K-12 Computer Science Standards, California’s Next Generation Standards, and the California Common Core Standards in English Language Development Standards and English Language Arts

California’s Environmental Principles and Concepts (EP&Cs)[3]	
Principle II	The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.
Principle II Concept A:	Direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.
Principle II Concept B:	Methods used to extract, harvest, transport and consume natural resources influence the geographic extent, composition, biological diversity, and viability of natural systems.
Principle II Concept C:	The expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems.
Computer Science Teacher Association Standards & California Computer Science Standards (CCSS)	
CSTA 1B-AP-10 (CCSS 3-5.AP.12)	Create programs that include sequences, events, loops, and conditionals.
CSTA 1B-AP-13	Use an iterative process to plan the development of a program by including others’ perspectives and considering user preferences.
CSTA 1B-AP-15 (CCSS 3-5.AP.17)	Test and debug a program or algorithm to ensure it runs as intended.
CSTA AB-AP-09 (CCSS 3-5.AP.11)	Create programs that use variables to store and modify data.
CSTA 1B-AP-12	Modify, remix, or incorporate portions of an existing program into one’s own work, to develop something new or add more advanced features.
English Language Development (ELD) Standards	
ELD.I2	Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia).
ELD.I6	Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language.
ELD.I.9	Expressing information and ideas in formal oral presentations on academic topics.
ELD.I.10	Write literary and informational text to present, describe, and explain ideas and information, using appropriate technology.
ELD.C.12	Selecting and applying varied and precise vocabulary and language structures to effectively convey ideas.
Corresponding English Language Arts Standards	
CCSS. ELA.RI.5.1	Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA.RI.5.9	Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

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[3] “The EP&Cs have become an important piece of the curricular expectations for all California students in science and other content areas” (California Science Framework 2016 CDE, Chapter 1, p. 53).

Linguistic scaffolding. The curriculum will include linguistic scaffolding that makes learning the concepts and building the projects more transparent and motivating for English language learners (Saito-Stehberger et al., 2021) by following recommendations from NASEM (2018), including engaging students in disciplinary discourse. Key concepts and terminology will be presented repeatedly in multiple modalities, including slide presentation, teacher explanation, workbook written activity, partner discussion, self-reflection, and peer assessment contexts. Language frames will be provided to support students in articulating concepts and processes they encountered in their projects. We will aim to prevent English learners' cognitive overload (Mayer & Moreno, 2003) by reducing the density of the text without simplifying content, for example, by aligning visual cues in the student workbook, slide presentation, and teacher's guide to support the repetition and reinforcement of key concepts and instruction.

Culturally-sustaining curricular integration. As in ACT 1 and ACT 2, we will integrate essential aspects of culturally-sustaining pedagogy into the ACT 3 curriculum so that the environmental and computational thinking concepts will resonate with our learners. We will affirm a sense of belonging to the CS and environmental fields, as students become familiar and comfortable with computing and environmental concepts, vocabulary, and processes. In the Role Model learning activities, for example, students will be introduced to professionals from diverse, underrepresented backgrounds in the CS and environmental fields and learn about both their careers and their lives in ways intended to highlight similarities with our students. Students will also practice understanding and valuing the perspectives of others through sharing work and seeking feedback from classmates. Additionally, students will have the opportunity to seek out the perspectives of community members through developing and implementing interview and survey questions. Students will also develop an awareness of impactful social structures by examining their community's environment and have avenues to actively share their awareness with others. Connecting culturally-sustaining pedagogy to science lessons can lead students to become more conscious about community environmental issues and environmental literacy (Upadhyay et al., 2020). By engaging in discourses about local environmental issues, students would be able to critically examine the economic, social, and cultural factors in their community, and see the connection between science content and local experience (Freire, 1998; Morales-Doyle, 2017; Seider et al., 2017).

Professional development for elementary teachers with minimal coding familiarity. Our team has gained insight and experience in providing professional development for our curriculum to novice computational thinking elementary teachers for the past six years. This is an especially valuable commodity because limited CS professional development resources are among the greatest barriers to expanding computer science education in schools (Yadav et al., 2016). The pivot to virtual summer professional development during the 2020 quarantine has resulted in a program with greater flexibility for our teachers, as well as more choice in how materials and instruction are distributed and practiced, and in how communities of practice are developed. Our summer professional development provides 14 synchronous hours on Zoom to respond to videos that were watched individually, to ask questions, and to build projects together. The elementary teachers can review materials and videos in our online learning management system and share successes and frustrations in the community discussion board that is accessible throughout the year. Monthly, teachers meet virtually to share experiences and receive on-going support with the curriculum. We have focused on building strong learning communities among the elementary teachers and provide easy access to content resources. Our teachers have been well prepared to teach the curriculum and have been enthusiastic to continue the next year.

Research Plan

The goals of this project will be to iteratively develop, implement, evaluate, and scale up an ACT 3 of the curriculum among 100 fifth-grade classrooms in the partner schools. As with the earlier work, we will conduct design-based implementation research centered on teacher instruction, student learning, and problems of teaching practice as identified by practitioners, students, and researchers (DBIR; Penuel et al., 2011). The research-practice partnership (RPP) is united in the following shared beliefs: that computer science is a fundamental discipline of 21st century life, that access to computer science education is highly unequal, that it needs to be systematically integrated into K-5 education so that all students have access to it before the critical high school years, and that it can and must be taught in an integrative way that builds on the linguistic and cultural resources of California's Latino and multilingual communities. Researchers and practitioners seek to better understand how students' language, literacy, science, and computer science learning can be simultaneously developed while strengthening diverse students' attitudes towards CS disciplines and careers through community-based learning.

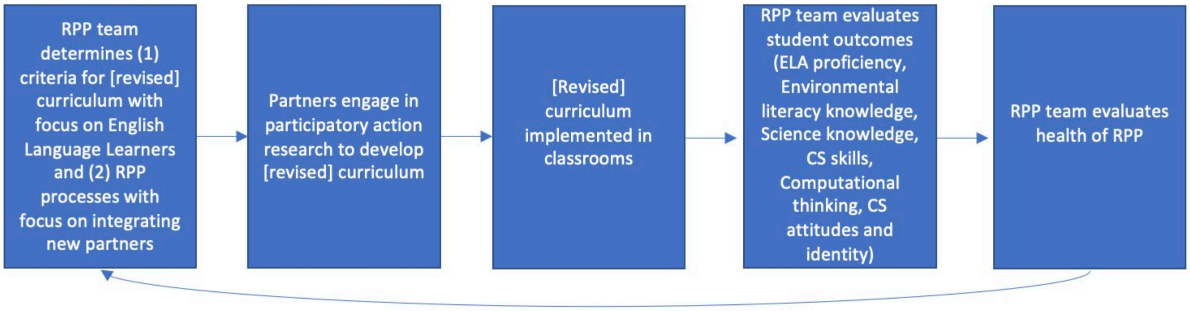

Figure 1. Theory of Action

Based on these beliefs, partners will engage in participatory action research to co-design the curriculum with a leadership team of UCI faculty, district representatives, and teachers (see theory of action in figure 1). The leadership team of UCI faculty and district representatives will meet monthly, and working groups will meet for a week in summer and monthly throughout the school year. Working groups are comprised of a UCI team of postdocs and graduate students, and SAUSD, MUSD, and El Sol teachers piloting the curriculum. At each stage of development, the health of the RPP will be assessed according to the five dimensions of effectiveness for assessing research-practice partnerships (Henrick et al., 2017): 1) building trust and cultivating partnership relationships; 2) conducting rigorous research to inform action; 3) supporting the partner practice organization in achieving its goals; 4) producing knowledge that can inform educational improvement efforts more broadly; and 5) building the capacity of participating researchers, practitioners, practice organizations, and research organizations to engage in partnership work.

In addition to our ongoing assessment of the RPP, we will also investigate the teaching and learning outcomes from the project using both qualitative and quantitative measures. As this is a mature partnership dating back to 2017, the school district partners are invested in pursuing rigorous evidence of the impact of the intervention on student learning and development, both for their internal purposes and to report to their key stakeholders.

The research questions will thus be as follows:

1. **Scaling up a research-practice partnership:** What are the challenges faced in expanding an equity-oriented RPP to additional school districts and grade levels and to integrations of new content, and how are those challenges best addressed?
2. **Teaching:** What are the best practices for integrating computer science and community-based environmental literacy among fifth-grade students with a high percentage of Latino English learners?
3. **Learning:** How does engagement with the curriculum affect the learning processes and outcomes of the students, including, environmental literacy knowledge, science knowledge, computational thinking, CS attitudes and identity, and academic language proficiency?

Table 3: Timeline

	Year 1				Year 2				Year 3				Year 4			
Activity	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**
Monthly design group mtg	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Co-design workshops		■	■		■	■	■		■	■	■					
Curriculum development	■	■	■	■	■	■	■	■	■	■	■	■				
Monthly teacher PD					■	■	■		■	■	■		■	■	■	
Summer PD				■				■				■				
Design group meeting notes	■	■	■		■	■	■		■	■	■		■	■	■	
Design group interviews			■				■				■				■	
Teacher interviews			■				■				■				■	
Teacher weekly surveys	■	■	■		■	■	■		■	■	■		■	■	■	
Teacher beliefs (TBaCCT)					■		■		■		■		■		■	
Student demographics	■			■	■			■	■			■	■			■
Student ELA scores							■				■				■	
ACES 3.0 pre and post					■		■		■		■		■		■	
ESCAS pre and post					■		■		■		■		■		■	
CAST (Calif. science test)							■				■				■	
Classroom observations	■	■	■		■	■	■		■	■	■		■	■	■	
Student interviews	■	■	■		■	■	■		■	■	■		■	■	■	
Scratch project assessments	■	■	■		■	■	■		■	■	■		■	■	■	
Data analysis	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Dissemination activities						■	■	■	■	■	■	■	■	■	■	■
Advisory Board meetings	■			■				■				■				■

We will conduct this project as follows.

Stage 1: Development and Initial Implementation (October 2023 to May 2024). During the first stage of the project, we will co-design the ACT 3 curriculum with three schools that have been especially close partners in CONECTAR 1.0 and 2.0: Rosewood Park Elementary in MUSD, Madison Elementary in SAUSD, and El Sol Science and Arts Academy. We will select a total of 10 fifth-grade teachers in these schools, about three in each, and implement the curriculum in these classes.

Working with the RPP leaders, we have identified three main projects to be conducted throughout the school year in the ACT 3 curriculum. All three projects will integrate environmental literacy, while promoting computational thinking and language and literacy. Students will create projects in Scratch about environmental issues in their own communities through modeling data, writing text, and presenting orally. The curriculum will provide example projects and scaffolded guidelines for instructors. The curriculum will follow the Universal Design for Learning framework and guide teachers to modify instructions to accommodate a broad range of learners and apply to a variety of learning contexts (Hansen et al., 2016; Israel et al., 2020). The projects will provide a motivating and meaningful context for multilingual students to practice literacy activities. Students will be empowered to address identified community issues while using their emerging academic language and multilingual skills (Cummins et al., 2015). For example, in projects 1 and 2, students can write their text to be presented orally in Spanish and translated to English. In project 3, students can present their stories in both English and Spanish to reach corresponding audiences. The general guidelines of the three projects are below (Table 4).

Table 4: Plans for the three projects to be implemented in ACT 3

	Project 1: Modeling Systems	**Project 2: Visualizing Data**	**Project 3: Communicating Science**
Description	Students will create an animated model of a system in their environment and community in the Scratch environment using events and conditionals after critically choosing key information for written texts and informative videos about systems. They will articulate the relationships between the parts.	Students will gather data in the community through surveys, interviews, and pictures. They will present their data in a Scratch project and will tell the story that the data represents.	Students will identify an environmental issue that confronts their community. Students will present alternative solutions to solve the environmental issue by modeling in Scratch. The Scratch project can be a game, public service announcement, or an animated message to email to stakeholders and policy makers. (NGSS 5-ESS2-1)
CS skills in alignment with CSTA standards	Students will use sequence, events, loops, and conditionals (1B-AP-10) to create interactive models to present cause-and-effect relationships and predict outcomes (1B-DA-07). Students will plan the development of a program by including others' perspectives (1B-AP-13) and debug a program to ensure it runs as intended (1B-AP-15).	Students will use Scratch variables to store and modify their data (1B-AP-09) to organize and present their data visually to highlight relationships and support a claim (1B-DA-06). Students will plan the development of a program by including others' perspectives (1B-AP-13) and debug a program to ensure it runs as intended (1B-AP-15).	Students will combine the CS skills used in projects 1 and 2 to present a scientific message in an innovative way.

Stage 2: Iterative Implementation and Improvement (June 2024 to May 2027). During the next stage of the project, we will carry out three cycles of implementation, evaluation, and iteration. In each year from 2024 to 2027 we will add 10 new schools with about 3 fifth-grade teachers in each (Table 5). Teachers from those schools will be provided 5 days of professional development in the summer, combined with a monthly PD meeting throughout the school year. At the same time, data will be collected throughout the school year to document teaching and learning processes and outcomes, and based on that and feedback from teachers and students, the curriculum will be steadily refined and improved.

Table 5: Teacher and student participation numbers (new schools and teachers in parentheses)

Year	Number of Schools	Number of Teachers	Number of students
2023-2024	3	10	300
2024-2025	13 (10)	40 (30)	1200
2025-2026	23 (10)	70 (30)	2100
2026-2027	33 (10)	100 (30)	3000
		Total Students Reached:	**6600**

Stage 3: Final Dissemination (June 2027 to September 2027). Though dissemination will be carried out throughout the project (described below), this effort will be amplified in the final months as the latest iteration of our curriculum will be disseminated broadly through our website. We will also make available in these final months a Spanish language version of the curriculum, as well as a highly accessible online professional development course (including videos and other instructional material), so that any individual teacher, school, or district can adopt the curriculum and learn (or help its teachers learn) to teach it.

Investigating the RPP. As the RPP expands to include two new partners, diversifies to now include both a charter school and two districts in addition to a university, broadens geographically to Los Angeles County in addition to Orange County, and widens its scope to address new grade levels and subject-matter integration, we want to take a more intentional look at the functioning of the RPP, to see what lessons we can share with others. Toward this end, for the first time we will incorporate both conjecture mapping (Sandoval, 2014) and equity conjectures (Lee et al., 2022).

The RPP functions through two levels of meetings—among the RPP leaders (2-3 representatives of each partner institution meeting together monthly) and the instructional groupings (UCI project staff and district teachers who also meet monthly and then for a full week in summer). Conjecture maps will iteratively be developed, shared, reviewed, and revised at both of these levels. At the beginning of the project, the RPP teams will develop conjectures about how the project is "embodied" (including what its tools and materials, task structure, participant structure, and discursive practices are); its mediating processes (how participants engage with those elements of embodiment to try to achieve intended outcomes); and our intended and expected outcomes. Drawing on principles of equity conjectures, we will identify what underlying social, economic, and educational contexts and power differentials pose threats to equity, and how we intend to address them. We will review these conjectures regularly throughout the process during the monthly design group meetings by reflecting on data from the professional development sessions, previous design group meeting notes, and classroom observations with the goal of better documenting the functioning of our RPP, the challenges that it faces, and its approach to addressing these challenges.

Each phase of the project will be implemented following the Plan-Do-Study-Act framework (Langley et al., 2009; Wilcox & Zuckerman, 2019). The RPP leaders and the instructional groups will collaboratively plan (set goals, assess curriculum, compare and select evidence-based practices), do (make an action plan, implement plan), study (monitor and evaluate progress, analyze findings), and act (implement the curriculum and assessment). The Plan-Do-Study-Act will be conducted in a cyclical manner during the monthly design group meeting to iteratively improve the curriculum, instruction, and assessments.

Sources of Data. We will gather the following RPP data, instructional practices, and learning outcome data:

Co-Design and RPP Process. Observation notes will be taken at co-design RPP meetings and workshops. The Plan-Do-Study-Act framework and equity conjecture map developed by the RPP team will be used to establish an observation protocol. In addition, key partners will be interviewed annually about the co-design process and RPP. Conjecture maps developed throughout will be collected and analyzed.

Class Observations. All participating teachers' classes in the study will be observed at least on a quarterly basis to examine effective instructional strategies to teach CS and environmental literacy to diverse learners while providing language scaffolding. All participating teachers will complete a weekly questionnaire to provide additional information on the fidelity of implementation. The 10 teachers who were a part of the curriculum development process in Year 1 will be observed once a month throughout the phases (Year 1-4). All observations will be recorded. The observations will be conducted using structured observation notes following the Universal Design for Learning (UDL) guidelines for computer science and computational thinking observation (Israel et al., 2020). We will use the observation protocol to note how teachers deploy the three dimensions of UDL (multiple opportunities for engagement, multiple means of representation, and multiple means of action and expression) and how they guide students through strategy development, concept development, and social interaction and discourse.

Student Interviews. We will interview the four diverse students from the 10 teachers' classes for the pre- and post-individual interviews of about 15-20 minutes. We will modify the semi-structured interview protocols we developed and implemented in CONECTAR 2.0. We developed this protocol from a ScratchEd rubric that assesses students' fluency with computational thinking practices, including experimenting and iterating, testing and debugging, reusing and remixing, and abstracting and modularizing. Open-ended questions that evoke a more conversational tone were modified from the existing rubric to capture in-depth data on student experiences while developing their computational thinking artifacts, students' attitudes towards computer science, and students' view of computer science in their community. We will add questions on students' attitudes towards environmental issues, and experiences with environmental issues in their community. Interviews will be recorded and transcribed.

Teacher Surveys and Interviews. All participating teachers will be interviewed at the end of their first year and on a selected basis in subsequent years with open-ended questions on their instructional strategies, teaching experiences, and feedback on the content and design of the curriculum. All teachers will also complete a weekly survey on their experience with the lessons and feedback which contains both multiple-choice and open-ended questions.

Teacher Beliefs. All participating teachers will be given the Teacher Beliefs about Coding and Computational Thinking (TBaCCT) survey, a validated instrument (Rich et al., 2021). TBaCCT will be given at the beginning of the year (pre) and end of the year (post) to measure how their attitudes about and self-efficacy for teaching coding and computational thinking change over time.

Computer Science Outcomes. All classes participating in the project will be given the Assessment of Computing for Elementary Computing (ACES) to assess the computational thinking skills of the students, an instrument developed and validated by our team, at the beginning and end of each school year (Parker et al., 2021). ACES questions measure the CT concepts of loops, sequences, conditionals, and variables for elementary school students and contain block-based coding questions and non-programming, Bebras-style questions (Parker et al., 2021). We will develop ACES 3.0 to align with the more advanced computational thinking skills taught in ACT 3 (i.e., loops with nesting, conditionals with complex conditions, simple functions) as a part of the current project and assess the validity and reliability of the measurement. In Year 1, we will create the first draft of the ACES 3.0 and administer the test starting in Year 2. Based on the data collected from Year 2, we will select questions to change or edit based on item difficulty and discrimination analyses, as well as student performance based on quartiles.

Computer science learning outcomes will also be measured through the collection and analysis of selected student Scratch projects. Scratch projects of four diverse students in each of the 10 key teachers' classes will be analyzed. For each class, two male students and two female students with varying levels of English language proficiency and academic achievement will be selected by the teachers. Students' environmental projects created in Scratch will be scored using a rubric developed by the RPP team. The development of the rubric will be guided by the extant rubrics that have been used for

ACT 1 and ACT 2 to grade student Scratch projects on the level of application of the CS skills learned (e.g., the complexity of the application of using conditionals in the code).

All classes participating in the project will be given the Elementary Student Coding Attitudes Survey (ESCAS), a validated instrument (Mason & Rich, 2020) that measures elementary school students' CS attitudes and identity including social value, coding confidence, coding interest, perception of coders, and coding utility, on a pre- and post-basis.

Environmental Literacy Outcomes. In addition to grading students' Scratch projects for CS skills and literacy, students' environmental literacy knowledge will be graded using the rubric created by the RPP team (described above) as guided by California's Environmental Principles and Concepts, and CA NGSS. Overall, the rubric for ACT 3 will consist of three components: CS skills, environmental literacy, and literacy skills. The students will be assessed on their ability to obtain and combine scientific information, use science ideas to communicate and address problems, and understand and communicate the effects of human activities in everyday life and ways for communities to protect the environment.

Science Knowledge Outcome. The NGSS-aligned annual California Science Test (CAST) scores will be collected for all fifth-grade students in the partnering districts, for students participating in the project as well as not participating in the project. CAST also integrates environmental literacy based on the connection between students' knowledge of California's adopted Environmental Principles and Concepts.

Language & Literacy Outcomes. The standardized assessment scores for the grade level English language arts/literacy tests will be collected and analyzed using the CAASPP ELA or an equivalent assessment used by the districts. Also, the literacy component from the Scratch rubric will be scored as guided by the English Language Arts standards on the level of literacy skills applied in the projects.

Data Analysis Plan. To answer the first research question on the challenges faced in expanding an equity-oriented RPP, we will first analyze transcript data and observation notes from co-design meetings and RPP meetings, and transcript data from the interviews with key partners to examine themes emerging in relation to challenges and problem-solving processes in scaling up an equity-oriented RPP. We will also analyze teachers' open-ended responses on their experience with each lesson in the teacher weekly surveys including teachers' challenges with the lesson, the relevance of the lesson, and interest in the lesson. We will use an inductive, grounded theory approach (Charmaz, 2006; Corbin & Strauss, 1990; Lee et al., 2022), with codes emerging directly from participant responses as well as more focused codes with our specific questions about each component of the Plan-Do-Study-Act and in developing the equity conjecture (Miles & Huberman, 1984). Data will be triangulated (e.g., themes that emerge across observations, design groups, and interviews will have triangulated data). Data collection and analysis will occur simultaneously each year (Corbin & Strauss, 2008; Miles & Huberman, 1984), and data from prior years will be used to inform subsequent years' data collection (Coburn, 2004). Then, we will compare the conjecture maps developed by the RPP team throughout the phases to note the developments and changes of the conjecture maps. These data will also directly inform the curriculum improvement process and the modifications made in the DBIR process.

To answer the second research question on the best practices for integrating computer science and community-based environmental literacy with the targeted group of learners, we will analyze the transcripts of participating teacher interviews and classroom observation notes. UCI researchers will iteratively code the transcripts to identify themes in instructional strategies and teaching practices as guided by the Universal Design for Learning framework to teach CS to elementary students (Israel et al., 2020). These coded themes will be further examined for any subordinate codes, using a grounded approach (Corbin & Strauss, 2008). In addition to using a priori themes to code the data, we will let any sub-themes emerge from the data that are important and relevant to improving the instructional materials. We will develop a codebook that details the superordinate and subordinate categories, code names and definitions, and examples from the data. Themes will be used to categorize instructional strategies used by teachers emerging from the interview and observation data.

The pre- and post- TBaCCT of teachers who participate in the curriculum will be triangulated with the transcription data to examine the plausible explanations of emergent themes and the relations between teacher practices and characteristics. TBaCCT data will also be analyzed in a manner similar to the student outcomes discussed below with respect to research question 3.

Learning assessments of students participating in the curriculum will be analyzed to examine the effect of teachers' instruction on students' learning processes and outcomes. We will explore which teaching practices and teacher characteristics are associated with higher learning outcomes for the students. For example, the Scratch project scores (includes CS skills, environmental literacy knowledge, literacy), ACES and CAST scores of students in participating teachers' classes will be analyzed to explore what teaching practices are associated with higher student learning outcomes. The themes on instructional strategies we find from the qualitative analysis will be used as covariates.

To answer the third research question on student learning, including in computer science, environmental literacy, science knowledge, CS attitudes and identity development, and language and literacy, we will calculate basic descriptive data for all students and our various student groups of interest. Although not randomly selected, we will also make use of district data on non-participating students with similar characteristics to estimate comparative differences in outcomes. We will also use multilevel modeling to estimate the impact of the curriculum on our outcomes for all participants, controlling for demographic factors at the student and school level, with controls for teacher/class and district. With respect to our ACES and ESCAS data, we will also examine internal consistency with Cronbach's alphas for the pre- and post-surveys; we will modify items for the sequential year if necessary to improve reliability. Finally, as discussed above for research question 2, we will use multilevel modeling to understand the impact of identified instructional strategies on student outcomes. Finally, pre- and post-individual interviews of the four students in each of the 10 key teachers' classes will be analyzed using thematic analysis to compare CS attitudes and identity, including the students' view of computer science in their community before and after the intervention.

Because we will not have a control condition, we will also perform fixed-effects propensity score matching by first estimating the propensity of treatment for each student in the sample using a logit model that includes all available covariates and district fixed effects. Based on the predicted probability of being in the treatment condition, we will match students in treatment and those fifth-grade students not receiving the curriculum using the nearest-neighbor method within caliper 0.1. Students in treatment with no near match (within 0.1 standard deviations of the propensity score) in the reference group will be dropped from the analysis resulting in a reduced sample size. The effects of treatment on each outcome measure, CAST and ELA scores, will be estimated separately for the matched sample using a regression analysis with controls for school fixed effects. We will also include all covariates in the post-match analysis to increase the precision of the treatment effect estimators. Then, we will interact the treatment variable with students' English language status in each regression model to examine heterogeneous effects.

Research Team

University of California, Irvine. ***Mark Warschauer*** (PI) is a Professor of Education and Informatics and a former Spanish bilingual mathematics teacher with a PhD in second language acquisition and expertise on computer science and STEM education among English language learners. He will be responsible for overall project management, maintenance of communication with school district partners, supervision of the graduate student researchers hired on the grant, and communication with the Advisory Board. ***Symone Gyles*** (Co-PI) is an Assistant Professor of Education with a BS in Marine and Environmental Sciences and a PhD in Education. She conducts research on co-design of curriculum with K-12 teachers that integrates environmental literacy and computational thinking from a social justice perspective. She will contribute expertise toward curriculum co-design and professional development. ***Debra Richardson*** (co-PI) is Professor Emerita of Informatics with a PhD in Computer and Information Science and former chair of both the ACM Computer Science Teachers Association Advisory Council and the California Computing Education Advocacy Network. She will contribute to the refinement of the curriculum and professional development materials and to dissemination with state and national organizations involved in computer science education. ***Clare Baek*** (Co-PI) is a Postdoctoral Scholar with a PhD in Urban Education Policy. A former computer science department chair in a network of charter schools, she has developed and implemented computer science curriculum targeted at the needs of diverse K-12 learners.

She will contribute to developing and implementing the curriculum, assessments, professional development, and conducting data analysis. ***Drew Bailey*** (Co-Investigator) is an Associate Professor of Education, Cognitive Sciences, and Psychological Science with expertise in longitudinal studies of children's learning and development in STEM. He will contribute expertise toward quantitative analyses. ***Leiny Garcia*** (Graduate Student Researcher) has degrees in engineering and learning sciences and extensive experience leading community coding programs. She will assist with data collection and analysis.

School District Partners. The following school district personnel will take the lead in overseeing the RPP in their districts and representing the RPP in broader team leadership meetings. **SAUSD:** ***Diana Torres***, Director of Elementary Curriculum & Instruction; ***Betsy Martinez***, coordinator of Elementary Student Achievement; and ***Lindsey Bogris***, Science Curriculum Specialist. **MUSD:** ***Kaivan Yuen***, Assistant Superintendent of Educational Services; ***Miguel Valencia***, Director of English Learners, Equity, and Innovation; and ***Scott Walker*****,** Science Program Specialist. **El Sol**: ***Monique Daviss***, Executive Director; and ***Ivet Gonzalez***, STEAM Coordinator and Academic Program Specialist.

Advisory Board: Feedback and Evaluation. Evaluation will be carried out by a four-member Advisory Board with extensive expertise in computer science or environmental literacy and in leading research practice partnerships. **Gerald Lieberman** is the Director of California's State Education Environmental Roundtable (SEER), which he founded in 1995. Dr. Lieberman has taken a leading role in developing and implementing California's environmental literacy standards and implementing the standards through professional development and curriculum development focusing on students' data-based investigations into their local communities. **Susan Gomez Zwiep** is a Senior Science Educator and Staff Advocate at BSCS Science and a Professor Emeritus of Science Education at CSU Long Beach, with extensive experience leading professional development initiatives to support effective science teaching for English learners and multilingual students in California's K-12 schools. **Katie Rich** is a senior researcher at the American Institutes for Research, where she serves as the principal investigator for an NSF-funded RPP with the state of Idaho focused on developing K-5 CS pathways for students throughout the state. **Dr. Kimberly Gomez** is a Professor in the Urban Schooling Division in the Department of Education at UCLA, with a joint appointment in Information Studies and is the principal investigator of an NSF Computer Science for All: Researcher-Practitioner Partnership (RPP) grant that focuses on how to effectively teach problem solving practices in 3rd–4th grade CS classes in low-income communities.

The Advisory Board (AB) will assess the project using the five objectives of the framework for assessing Research-Practice Partnerships (Henrick et al., 2017). To accomplish these objectives, the AB will conduct a systematic review of project materials supplied by the project team, including but not limited to draft summaries of the work of the RPP, overviews of the research being conducted, instruments and their accompanying technical documentation, interim data products, and draft reports of findings. In early fall of 2023, a detailed Year 1 plan and project narrative will be submitted to the AB. The AB will address the five project dimensions above in relationship to the overarching goals of the project.

This process will be repeated each summer, except that the project team will also provide preliminary results, draft manuscripts, and presentations. In summer 2027, the AB will conduct a summative evaluation of the project. The project team will provide an overview of the project accomplishments, including the final developed modules, results of the pilot, and information on dissemination. While addressing the five framework dimensions listed above, the AB will focus on particular summative questions such as whether the project team completed the goals of the project as set forth in this proposal and what follow-up steps are advised so as to best continue the partnership and work beyond this grant.

Dissemination

We will reach out to the following audiences with information about our project and its progress: district stakeholders, other educational leaders and practitioners in Orange County and the nation, scholars interested in related topics, legislators and policy makers, and the broader public.

We will reach out to **SAUSD, MUSD, and El Sol stakeholders** through regular presentations to leadership cabinets, district meetings of elementary school principals, presentations at the Board of Education, letters and newsletters to parents in the participating schools, showcase events where relatives and friends can come view students' Scratch projects, and information on school and District websites. To reach out to **California educators**, we will offer workshops at the Los Angeles and Orange County Departments of Education and at school districts within the counties that demonstrate interest. We will also invite district representatives to visit project classrooms. The Elementary Computing for All project is also participating in the California statewide summer of CS program by offering free PD workshops to teachers throughout the State in summer and will continue to do so.

We will reach out to **educators across the country** interested in CS education, elementary education, environmental education and STEM Education for English learners through presentations and workshops at practitioner-oriented conferences including those hosted by the ACM Special Interest Group on Computer Science Education (SIGCSE), the Computer Science Teacher Association (CSTA), the National Science Teachers Association, Computer Using Educators (CUE), EdSurge Fusion, and Digital Promise. We will also submit papers to teacher-oriented publications, including the *ACM SIGCSE Technical Symposium*, *The CSTA VOICE, Computers in the Schools,* and *TESOL Journal*. Co-PI Richardson serves as chair of the CSTA Advisory Council, worked to establish the Orange County CSTA Chapter, and has also been active in SIGCSE; she will pursue opportunities to engage with these audiences.

We will reach out to **scholars** interested in research on teaching of CS to diverse learners through presentations at appropriate academic venues such as the ACM SIGCSE Technical Symposium; Research on Equity & Sustained Participation in Computing, Engineering, & Technology; International Computing Education Research; the National Association of Research on Science Teaching, the International Society of the Learning Sciences, and the American Educational Research Association. We will submit papers to peer-reviewed journals in areas related to the project, including *Educational Researcher*, *Computer Science Education*, *Computers & Education*, *Research in Science Education, Journal of the Learning Sciences,* and *TESOL Quarterly*.

To reach **legislators and policy makers**, co-PI Richardson will share information through the Alliance for California Computing Education for Students and Schools (ACCESS), the leading advocate for CS education in California and a group that she previously chaired. To reach the **broad public**, a popular summary of the study will be submitted to *The Conversation* and information will be shared with EdSurge, both venues that have published prior project work by Warschauer, and information on the project will be included in the magazines, newsletters, and media productions of the UCI School of Education.

The project **website** will reach all of the abovementioned audiences. PI Warschauer's research projects are all shared on his Digital Learning Lab website, which is one of the most widely-visited research sites at UCI. The project's website will include links to curriculum, publications, presentations, reports, news articles, commentary, and, eventually, information on how to obtain data from the study.

Broader Impacts

The project will directly reach 6,600 fifth-grade students, more than 95% of whom are Latino and about half of whom are designated as English learners, with a **culturally-sustaining computer science and environmental literacy curriculum,** and provide professional development so that these districts can continue offering the curriculum on an ongoing basis. In addition, both the curriculum and professional development materials will be freely shared online together with the current Elementary Computing for All resources, which are already being used in a number of school districts throughout the US that serve high percentages of Latino students and English learners. The project will draw on and train a diverse group of graduate and undergraduate student researchers at UCI, including fellows from an equity-focused undergraduate training program, Career Pathways for Researching Learning and Education, Analytics and Data Science.